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Specification

Method and Device for Drying Substrate

Technical Field

The present invention relates to a method and device for drying substrates. More particularly, the present invention relates to a method and device for rapidly drying substrates which are cleaned using cleaning fluid.

Related Art

From the past, a device having an arrangement which is illustrated in Japanese Patent Publication Gazette No. Hei 6-103686, U.S. Patent No. 5,964,958 and others is proposed as a device for drying substrates (for example, semiconductor wafer or the like) after cleaning of the substrates using cleaning fluid, by relatively lowering the fluid face of the cleaning fluid with respect to the substrates and by supplying drying fluid vapor {for example, isopropyl alcohol (hereinafter referred to as IPA) vapor or the like}.

When the device is employed, a plurality of substrate housed within a processing vessel is cleaned using the cleaning fluid, then the drying fluid vapor is introduced within the processing vessel and the fluid face of the cleaning fluid is lowered, both operations are carried out simultaneously, so that a thin fluid layer of drying fluid is generated on the fluid face of the cleaning fluid. Consequently, the surface of each substrate is rapidly dried using MARANGONI effect.

When the device having the arrangement illustrated in Japanese Patent Publication Gazette No. Hei 6-103686 is employed, not only an introducing passage for introducing drying vapor but also a relief valve (exhaust opening) for exhausting drying vapor are needed for forming a flowing passage of drying vapor within the processing vessel so that the arrangement

becomes complicated and that a dangerous condition is realized in which the drying vapor leak within a factory.

Further, when the device is applied for drying a plurality of semiconductor wafer, the semiconductor wafer is enlarged in size, and an interval of semiconductor wafer is decreased for increasing a number of semiconductor wafer which are processed simultaneously, in recent years. Under such condition, a disadvantage arises in that intruding of the drying vapor between semiconductor wafers becomes difficult so as to generate a drying mark on the semiconductor wafers.

Furthermore, when each substrate such as a semiconductor wafer has a pattern having a thickness to some degree, the thickness of the fluid layer of drying fluid should be increased to some degree for sufficiently and rapidly drying within inner section (concave section) of the pattern. But, it is difficult to increase the thickness of the fluid layer of drying fluid sufficiently in the entire surface of the substrates. Therefore, the inner section of the pattern cannot be dried sufficiently so that cleaning fluid remains on the surface of the substrates. In other words, the device cannot deal sufficiently for the substrates having a higher aspect ratio.

The present invention was made in view of the above problems.

It is an object of the present invention to offer a method and device for drying substrate in which an exhaust equipment is eliminated or simplified and for smoothly supplying drying fluid and for sufficiently increasing a thickness of a fluid layer of drying fluid.

Disclosure of the Invention

A method for drying substrate of claim 1 houses substrates within a processing vessel, and dries a surface of each substrate by relatively lowering a fluid face of cleaning fluid within a

processing vessel with respect to the substrate and by introducing the cleaning fluid within the processing vessel, the method comprises the steps of,

Introducing drying fluid under a liquid condition within the processing vessel, and

Forming liquid drops of drying fluid and supplying the liquid drops onto the fluid face of the cleaning fluid using a nozzle.

Wherein, the liquid drop is preferable to have a diameter which is greater than 100 μ m and equal to or less than 1 mm. The liquid drop is more preferable to have a diameter which is greater than 100 μ m and equal to or less than 200 μ m.

A method for drying substrate of claim 2 houses the substrates within the processing vessel in an inclined condition by a predetermined angle, and supplies the liquid drops of drying fluid using the nozzle in a direction which is the same direction of the inclined substrates.

Wherein, the inclination angle is preferable to be greater than 0° and equal to or less than 30° . The inclination angle is more preferable to be equal to or greater than 3° and equal to or less than 5°

A method for drying substrate of claim 3 determines an introduction direction of the drying fluid into the processing vessel and determines an introduction initial speed of the drying fluid so as to expand the drying fluid up to the entire width of the substrates on the fluid surface of the cleaning fluid.

Wherein, the introduction initial speed is preferable to be equal to or greater than 10 m/sec and equal to or less than 330 m/sec. The introduction initial speed is more preferable to be equal to or greater than 50 m/sec and equal to or less than 150 m/sec.

A method for drying substrate of claim 4 supplies inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel.

A method for drying substrate of claim 5 increases the supplying quantity of the drying fluid and/or the inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel.

A method for drying substrate of claim 6 changes supporting position of the substrates following exhausting of the cleaning fluid from the processing vessel.

A method for drying substrate of claim 7 makes the interior of the processing vessel to be inert gas environment prior to exhausting of the cleaning fluid from the processing vessel.

A method for drying substrate of claim 8 carries out the cleaning process and the following drying processing under a room temperature.

A method for drying substrate of claim 9 flows the drying fluid by the pressure of inert gas which is supplied to the nozzle.

A device for drying substrate of claim 10 supports substrates within a processing vessel by supporting means, and dries a surface of each substrate by relatively lowering a fluid face of cleaning fluid within a processing vessel with respect to the substrate and by introducing the cleaning fluid within the processing vessel, the device comprises,

Drying fluid supplying means for introducing drying fluid under a liquid condition within the processing vessel, for forming liquid drops of drying fluid using a nozzle, and for supplying the liquid drops of drying fluid onto the fluid face of the cleaning fluid using a nozzle.

Wherein, the liquid drop is preferable to have a diameter which is greater than 100 μ m and equal to or less than 1 mm. The liquid drop is more preferable to have a diameter which is greater than 100 μ m and equal to or less than 200 μ m.

A device for drying substrate of claim 11, wherein the supporting means is the means for supporting the substrates within the processing vessel in an inclined condition by a predetermined angle, and the nozzle is a nozzle for supplying the liquid drops of

drying fluid using the nozzle in a direction which is the same direction of the inclined substrates.

Wherein, the inclination angle is preferable to be greater than 0° and equal to or less than 30°. The inclination angle is more preferable to be equal to or greater than 3° and equal to or less than 5°

A device for drying substrate of claim 12, wherein the drying fluid supplying means is a means for determining an introduction direction of the drying fluid into the processing vessel and determines an introduction initial speed of the drying fluid so as to expand the drying fluid up to the entire width of the substrates on the fluid surface of the cleaning fluid.

Wherein, the introduction initial speed is preferable to be equal to or greater than 10 m/sec and equal to or less than 330 m/sec. The introduction initial speed is more preferable to be equal to or greater than 50 m/sec and equal to or less than 150 m/sec.

A device for drying substrate of claim 13 further comprises inert gas supplying means for supplying inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel.

A device for drying substrate of claim 14 further comprises supplying quantity control means for increasing the supplying quantity of the drying fluid and/or the inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel.

A device for drying substrate of claim 15, wherein the supporting means is a means having a cleaning fluid introduction groove which follows in lower ward direction with respect to the substrate supporting section.

A device for drying substrate of claim 16, wherein the supporting means is a pair of supporting means for selectively supporting different positions of the substrates which positions are different from one another, and further comprises supporting

position control means for changing the supporting position of the substrates by the supporting means following exhausting of the cleaning fluid from the processing vessel.

A device for drying substrate of claim 17 further comprises environment determination means for making the interior of the processing vessel to be inert gas environment prior to exhausting of the cleaning fluid from the processing vessel.

A device for drying substrate of claim 18 further comprises nozzle position control means for moving the nozzle towards the substrates following exhausting of the cleaning fluid from the processing vessel.

Wherein the movable extent of the nozzle by the nozzle position control means is preferable to be greater than 0 mm and equal to or less than 500 mm. The movable extent is more preferable to be equal to or greater than 250 mm and equal to or less than 350 mm.

A device for drying substrate of claim 19 further comprising circulation means for circulating the drying fluid when ejection is not carried out.

A device for drying substrate of claim 20, wherein a number of nozzles is determined in response to response to the size of the substrate and the pitch of the substrates.

A device for drying substrate of claim 21, wherein the nozzle has drying fluid ejection holes a number of which is greater than the number of the substrates by 1 which substrates are dried simultaneously.

A device for drying substrate of claim 22 further comprises inert gas supplying means for supplying inert gas to the nozzle so as to flow the drying fluid by the pressure of inert gas.

When the method for drying substrate of claim 1 is employed, the method houses substrates within the processing vessel, and dries the surface of each substrate by relatively lowering the fluid face of cleaning fluid within the processing vessel with respect to

the substrate and by introducing the drying fluid within the processing vessel.

During this operation, the method forms liquid drops of drying fluid using the nozzle, supplies the liquid drops of drying fluid onto the fluid face of the cleaning fluid using a nozzle. Therefore, the liquid drops of drying fluid is smoothly introduced between the substrates due to the influence of dead weight of the liquid conditioned drying fluid so that the drying fluid with high density with respect to the density of the vapor supplying so as to improve MARANGONI effect. Consequently, a liquid layer of the drying fluid having a sufficient thickness is generated on the cleaning fluid so that drying of the substrates with greatly little drying mark is rapidly realized using MARANGONI effect. Further, the thickness of the fluid layer of the drying fluid can be determined to be sufficiently great so that securely drying is performed up to the inner section (concave section) of a pattern even when the substrate has the pattern. Consequently, the method can deal with the high aspect ratio substrates and securely prevents the cleaning fluid from remaining on the surface of the substrates. Further, the drying fluid is supplied in a liquid drop condition, so that the entirety or almost of the drying fluid is discharged with the cleaning fluid. Consequently, leakage of the drying fluid is decreased up to nearly zero so that exhaust equipment is eliminated or is simplified. As a result, decrease in cost is realized.

In this case, when the liquid drop of drying fluid has a diameter which is greater than 100 μm and equal to or less than 1 mm, the above operation is realized following the supplying of the liquid drops. The liquid drop is more preferable to have a diameter which is greater than 100 μm and equal to or less than 200 μm. Disadvantages are prevented from occurrence such that the substrates are dried insufficiently due to shortage of supplying quantity of the drying fluid, that the cleaning fluid jumps so that the cleaning fluid is adhered to the substrates, and that the running cost is increased due to the increase of the drying fluid.

When the method for drying substrate of claim 2 is employed, the method houses the substrates within the processing vessel in an inclined condition by a predetermined angle, and supplies the liquid drops of drying fluid using the nozzle in a direction which is the same direction of the inclined substrates. Therefore, when each substrate has a pattern on one face and when the pattern formed face of a plurality of substrates are positioned in the same side, exhausting of the cleaning fluid is easily performed which is introduced within the inner section of the pattern so that more rapid and better drying is realized.

In this case, when the inclination angle is greater than 0° and equal to or less than 30°, the above operation is realized. The inclination angle is more preferable to be equal to or greater than 3° and equal to or less than 5°. Disadvantages are prevented from occurrence such that the cleaning fluid within the inner section of the pattern is difficult to be exhausted, that the drying fluid is difficult to be supplied to the dipping boundary face, and that the cleaning fluid exhausted from the pattern drops onto the neighboring substrate. In addition, the above operation is realized.

When the method for drying substrate of claim 3 is employed, the method determines an introduction direction of the drying fluid into the processing vessel and determines an introduction initial speed of the drying fluid so as to expand the drying fluid up to the entire width of the substrates on the fluid surface of the cleaning fluid. Therefore, even when the substrates become enlarged in diameter and/or when the interval between the substrates is decreased, the liquid drops of drying fluid are smoothly supplied into the gap between the substrates and the liquid layer of the drying fluid is continuously formed on the liquid face of the cleaning fluid so that rapid drying of the substrates is realized without drying marks. Further, the density of the drying fluid is not needed to be raised too high and the temperature of the drying fluid is not needed to be raised too high, so that the running cost is decreased. Also, though the drying fluid has explosiveness due to

the inflammability of the drying fluid when the drying fluid is mixed with air, the explosiveness can be suppressed so that safety is improved.

In this case, when the introduction initial speed is equal to or greater than 10 m/sec and equal to or less than 330 m/sec, the above operation is realized. The introduction initial speed is more preferable to be equal to or greater than 50 m/sec and equal to or less than 150 m/sec. Disadvantages are prevented from occurrence such that the liquid drops of the drying fluid are not smoothly supplied to the gap between the substrates, and that vibration of the liquid surface of the cleaning fluid or the like becomes greater, so that the speed of the liquid face becomes a speed which is substantially greater than the optimum speed of MARANGONI drying, consequently the cleaning fluid remains on the surface of the substrates.

When the method for drying substrate of claim 4 is employed, the method supplies inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel. Therefore, the interior of the processing vessel becomes negative pressured condition following exhausting of the cleaning fluid so that particles are prevented from intruding from the exterior.

When the method for drying substrate of claim 5 is employed, the method increases the supplying quantity of the drying fluid and/or the inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel. Therefore, the liquid drops of the drying fluid are securely supplied to the liquid face of the cleaning fluid by increasing the supplying quantity following exhausting of the cleaning fluid so that the thickness of the liquid layer of the drying fluid on the cleaning fluid is continuously maintained to be equal to or greater than a predetermined thickness.

When the method for drying substrate of claim 6 is employed, the method changes supporting position of the substrates following exhausting of the cleaning fluid from the processing vessel.

Therefore, the supporting position of the substrates is also rapidly and securely dried.

When the method for drying substrate of claim 7 is employed, the method makes the interior of the processing vessel to be inert gas environment prior to exhausting of the cleaning fluid from the processing vessel. Therefore, generation of water mark on the surface of the substrate is greatly suppressed.

When the method for drying substrate of claim 8 is employed, the method carries out the cleaning process and the following drying processing under a room temperature. Therefore, heating process is not needed at all, so that simplification in arrangement in entire system is realized and that safety is improved.

When the method for drying substrate of claim 9 is employed, the method flows the drying fluid by the pressure of inert gas which is supplied to the nozzle. Therefore, driving section for supplying the drying fluid is not needed at all, and cleanness is improved by preventing particles from mixing and intruding.

When the device for drying substrate of claim 10 is employed, the device supports substrates within a processing vessel by supporting means, and dries a surface of each substrate by relatively lowering a fluid face of cleaning fluid within a processing vessel with respect to the substrate and by introducing the cleaning fluid within the processing vessel.

During this operation, the device forms liquid drops of drying fluid using the nozzle, supplies the liquid drops of drying fluid onto the fluid face of the cleaning fluid using a nozzle by the drying fluid supplying means.

Therefore, the liquid drops of drying fluid is smoothly introduced between the substrates due to the influence of dead weight of the liquid conditioned drying fluid so that the drying fluid with high density with respect to the density of the vapor supplying so as to improve MARANGONI effect. Consequently, a liquid layer of the drying fluid having a sufficient thickness is generated on the cleaning fluid so that drying of the substrates with

greatly little drying mark is rapidly realized using MARANGONI effect. Further, the thickness of the fluid layer of the drying fluid can be determined to be sufficiently great so that securely drying is performed up to the inner section (concave section) of a pattern even when the substrate has the pattern. Consequently, the method can deal with the high aspect ratio substrates and securely prevents the cleaning fluid from remaining on the surface of the substrates. Further, the drying fluid is supplied in a liquid drop condition, so that the entirety or almost of the drying fluid is discharged with the cleaning fluid. Consequently, leakage of the drying fluid is decreased up to nearly zero so that exhaust equipment is eliminated or is simplified. As a result, decrease in cost is realized.

In this case, when the liquid drop of drying fluid has a diameter which is greater than 100 μm and equal to or less than 1 mm, the above operation is realized following the supplying of the liquid drops. The liquid drop is more preferable to have a diameter which is greater than 100 μm and equal to or less than 200 μm. Disadvantages are prevented from occurrence such that the substrates are dried insufficiently due to shortage of supplying quantity of the drying fluid, that the cleaning fluid jumps so that the cleaning fluid is adhered to the substrates, and that the running cost is increased due to the increase of the drying fluid.

When the device for drying substrate of claim 11 is employed, the device employs the supporting means which supports the substrates within the processing vessel in an inclined condition by a predetermined angle, and the device employs the nozzle which supplies the liquid drops of drying fluid using the nozzle in a direction which is the same direction of the inclined substrates.

Therefore, when each substrate has a pattern on one face and when the pattern formed face of a plurality of substrates are positioned in the same side, exhausting of the cleaning fluid is easily performed which is introduced within the inner section of the pattern so that more rapid and better drying is realized.

In this case, when the inclination angle is greater than 0° and equal to or less than 30°, the above operation is realized. The inclination angle is more preferable to be equal to or greater than 3° and equal to or less than 5°. Disadvantages are prevented from occurrence such that the cleaning fluid within the inner section of the pattern is difficult to be exhausted, that the drying fluid is difficult to be supplied to the dipping boundary face, and that the cleaning fluid exhausted from the pattern drops onto the neighboring substrate. In addition, the above operation is realized.

When the device for drying substrate of claim 12 is employed, the device employs the drying fluid supplying means which determines an introduction direction of the drying fluid into the processing vessel and determines an introduction initial speed of the drying fluid so as to expand the drying fluid up to the entire width of the substrates on the fluid surface of the cleaning fluid.

Therefore, even when the substrates become enlarged in diameter and/or when the interval between the substrates is decreased, the liquid drops of drying fluid are smoothly supplied into the gap between the substrates and the liquid layer of the drying fluid is continuously formed on the liquid face of the cleaning fluid so that rapid drying of the substrates is realized without drying marks. Further, the density of the drying fluid is not needed to be raised too high and the temperature of the drying fluid is not needed to be raised too high, so that the running cost is decreased. Also, though the drying fluid has explosiveness due to the inflammability of the drying fluid when the drying fluid is mixed with air, the explosiveness can be suppressed so that safety is improved.

In this case, when the introduction initial speed is equal to or greater than 10 m/sec and equal to or less than 330 m/sec, the above operation is realized. The introduction initial speed is more preferable to be equal to or greater than 50 m/sec and equal to or less than 150 m/sec. Disadvantages are prevented from occurrence such that the liquid drops of the drying fluid are not smoothly

supplied to the gap between the substrates, and that vibration of the liquid surface of the cleaning fluid or the like becomes greater, so that the speed of the liquid face becomes a speed which is substantially greater than the optimum speed of MARANGONI drying, consequently the cleaning fluid remains on the surface of the substrates.

When the device for drying substrate of claim 13 is employed, the device further comprises inert gas supplying means for supplying inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel. Therefore, the interior of the processing vessel becomes negative pressured condition following exhausting of the cleaning fluid so that particles are prevented from intruding from the exterior.

When the device for drying substrate of claim 14 is employed, the device further comprises supplying quantity control means for increasing the supplying quantity of the drying fluid and/or the inert gas into the processing vessel following exhausting of the cleaning fluid from the processing vessel. Therefore, the liquid drops of the drying fluid are securely supplied to the liquid face of the cleaning fluid by increasing the supplying quantity following exhausting of the cleaning fluid so that the thickness of the liquid layer of the drying fluid on the cleaning fluid is continuously maintained to be equal to or greater than a predetermined thickness.

When the device for drying substrate of claim 15 is employed, the device employs the supporting means which have a cleaning fluid introduction groove which follows in lower ward direction with respect to the substrate supporting section. Therefore, drainage of the cleaning fluid at the substrate supporting section is improved.

When the device for drying substrate of claim 16 is employed, the device employs a pair of supporting means for selectively supporting different positions of the substrates which positions are different from one another, and the device further comprises supporting position control means for changing the supporting position of the substrates by the supporting means following

exhausting of the cleaning fluid from the processing vessel. Therefore, the supporting position of the substrate is also dried rapidly and securely.

When the device for drying substrate of claim 17 is employed, the device further comprises environment determination means for making the interior of the processing vessel to be inert gas environment prior to exhausting of the cleaning fluid from the processing vessel. Therefore, generation of water mark on the surface of the substrate is greatly suppressed.

When the device for drying substrate of claim 18 is employed, the device further comprises nozzle position control means for moving the nozzle towards the substrates following exhausting of the cleaning fluid from the processing vessel. Therefore, the drying fluid with sufficient quantity is supplied onto the liquid face of the cleaning fluid without changing the introduction initial speed and the introduction flowing quantity of the liquid drops of the drying fluid.

In this case, the movable extent of the nozzle by the nozzle position control means is preferable to be greater than 0 mm and equal to or less than 500 mm so that the above operation is realized. The movable extent is more preferable to be equal to or greater than 250 mm and equal to or less than 350 mm. Disadvantages are prevented from occurrence such that the drying fluid does not intrude to the gap between the substrates, and that vibration of the liquid surface of the cleaning fluid or the like becomes greater, so that the speed of the liquid face becomes a speed which is substantially greater than the optimum speed of MARANGONI drying, consequently the cleaning fluid remains on the surface of the substrates.

When the device for drying substrate of claim 19 is employed, the device further comprising circulation means for circulating the drying fluid when ejection is not carried out. Therefore, the pressure of the space in which the drying fluid exists is always determined to be greater than the pressure in exterior so as to prevent particles from intruding from exterior, and the usage

quantity of the drying fluid is reduced so as to decrease the running cost.

When the device for drying substrate of claim 20 is employed, the device employs the nozzles a number of which is determined in response to response to the size of the substrate and the pitch of the substrates. Therefore, uniformly drying is realized on the entire face of the substrate.

When the device for drying substrate of claim 21 is employed, the device employs the nozzle which has drying fluid ejection holes a number of which is greater than the number of the substrates by 1 which substrates are dried simultaneously. Therefore, liquid drops of the drying fluid are supplied to every gap between the substrates and the outer side of the substrates which are positioned at both ends so as to dry the entire surface of each substrate rapidly and uniformly (without generation of water mark).

When the device for drying substrate of claim 22 is employed, the device further comprises inert gas supplying means for supplying inert gas to the nozzle so as to flow the drying fluid by the pressure of inert gas. Therefore, driving section for supplying the drying fluid is not needed at all, and cleanness is improved by preventing particles from mixing and intruding.

Brief Description of the Drawings

Figure 1 is a schematic diagram illustrating an arrangement of a substrate processing apparatus of an example in which a device for drying substrate according to the present invention is applied;

Figure 2 is an enlarged cross sectional view illustrating an arrangement of a first substrate supporting section;

Figure 3 is a schematic diagram illustrating a main section of a substrate processing apparatus of another example;

Figure 4 is a schematic diagram illustrating a main section of a substrate processing apparatus of a further example;

Figure 5 is a schematic diagram illustrating a main section of a substrate processing apparatus of a yet example;

Figure 6 is a schematic diagram illustrating a main section of a substrate processing apparatus of yet another example;

Figure 7 is a schematic diagram illustrating a fluid nozzle for drying under a downward moved condition;

Figure 8 is a schematic diagram illustrating a main section of a substrate processing apparatus of a yet further example;

Figure 9 is a schematic cross sectional view illustrating a cleaning fluid decreased condition;

Figure 10 is a schematic cross sectional view illustrating a substrate transferring condition;

Figure 11 is a schematic vertical cross sectional view illustrating a condition after the substrate has transferred;

Figure 12 is a schematic diagram illustrating a main section of a substrate processing apparatus of a further example;

Figure 13 is an enlarged cross sectional view of a substrate which is applied to the substrate processing apparatus illustrated in Fig. 12; and

Figure 14 is a schematic diagram illustrating a main section of a substrate processing apparatus of a yet further example.

Best Mode for Carrying Out the Invention

Hereinafter, referring to the attached drawings, we explain a method and device for drying substrate of an embodiment according to the present invention in detail.

Fig. 1 is a schematic diagram illustrating an arrangement of a substrate processing apparatus of an example in which a device for drying substrate according to the present invention is applied.

This substrate processing apparatus comprises a processing vessel 2 for housing a predetermined number of substrates 1 such as semiconductor wafer or the like which substrates 1 stand in parallel to one another, a first substrate supporting section 3 for supporting the substrates 1 within the processing vessel 2, a

processing fluid supplying section 4 for supplying processing fluid (for example, pure water, deionized water, deoxidized water or the like when cleaning processing is carried out) 11 into the processing vessel 2 which processing fluid 11 is used for performing processing such as cleaning processing or the like for the substrates 1, an exhausting section 5 for exhausting the processing fluid 11 from the processing vessel 2, and a drying fluid supplying section 6 for supplying liquid drops 12 of drying fluid into the processing vessel 2 which drying fluid is used for performing drying processing for the substrates 1. The apparatus further comprises a control section 10 such as micro computer or the like which controls the operation of the processing fluid supplying section 4, the exhausting section 5, and the drying fluid supplying section 6.

The first substrate supporting section 3 has a main body member 3a and a plurality of supporting groove 3b having a cross sectional V shape formed on the upper face of the main body member 3a, as is illustrated in Fig. 2. It is preferable that a slit 3c is further provided which elongates downward from the bottom section of each supporting groove 3b so as to improve drainage. It is more preferable that a round hole 3d is provided which is connected to the bottom section of the slit 3c so as to further improve drainage.

The processing fluid supplying section 4 has a processing fluid tank 4a, a processing fluid supplying pipe 4b for guiding the processing fluid 11 out from the processing fluid tank 4a, an open and close valve 4c and a pump 4f each provided at a predetermined position of the processing fluid supplying pipe 4b, a processing fluid nozzle 4d for blowing the processing fluid 11 into the processing vessel 2 which processing fluid 11 is supplied through the processing fluid supplying pipe 4b, and a regulation plate 4e for regulating the processing fluid 11 injected from the processing fluid nozzle 4d and for supplying the processing fluid 11 towards the substrates 1 housed within the processing vessel 2.

The exhausting section 5 has an exhausting pipe 5a provided at a predetermined position of the bottom section of the processing

vessel 2, an open and close valve 5b provided at a predetermined position of the exhausting pipe 5a, and a waste tank 5c for housing the processing fluid exhausted through the exhausting pipe 5a.

The drying fluid supplying section 6 has a drying fluid tank 6a for housing the drying fluid (fluid having a surface tension which is smaller than that of the processing fluid) made of substantially non-reactive liquid such as isopropyl alcohol (IPA), ethyl alcohol, methyl alcohol, tetrahydrofuran, acetone, perfluorohexane, hexane or the like, a drying fluid supplying pipe 6b for guiding the drying fluid from the drying fluid tank 6a, an open and close valve 6c and a pump 6e each provided at a predetermined position of the drying fluid supplying pipe 6b, and a drying fluid nozzle 6d for blowing the drying fluid as liquid drops into the processing vessel 2 which drying fluid is supplied through the drying fluid supplying pipe 6b. The drying fluid nozzle 6d is sufficient that diameter of each liquid drop blowing opening and the like are determined so as to form the liquid drops 12 each has a diameter which is greater than 100 μ m and equal to or less than 1 mm. The drying fluid nozzle 6d is preferable that diameter of each liquid drop blowing opening and the like are determined so as to form the liquid drops 12 each has a diameter which is greater than 100 μ m and equal to or less than 200 μ m. When the diameter of each liquid drop is determined in such manner, disadvantages are prevented from occurrence such that the substrates are dried insufficiently due to shortage of supplying quantity of the drying fluid, that the cleaning fluid jumps so that the cleaning fluid is adhered to the substrates, and that the running cost is increased due to the increase of the drying fluid. Further, the drying fluid nozzle 6d is sufficient that inner diameter of the drying fluid nozzle 6d, diameter of each liquid drop blowing opening and the like are determined so as to determine the blowing speed of the liquid drops 12 to be equal to or greater than 10 m/sec and equal to or less than 330 m/sec. The drying fluid nozzle 6d is preferable that inner diameter of the drying fluid nozzle 6d, diameter of each

liquid drop blowing opening and the like are determined so as to determine the blowing speed of the liquid drops 12 to be equal to or greater than 120 m/sec and equal to or less than 220 μ m. When the blowing speed of the liquid drops is determined in such manner, disadvantages are prevented from occurrence such that the liquid drops of the drying fluid are not smoothly supplied to the gap between the substrates, and that vibration of the liquid surface of the cleaning fluid or the like becomes greater, so that the speed of the liquid face becomes a speed which is substantially greater than the optimum speed of MARANGONI drying, consequently the cleaning fluid remains on the surface of the substrates. Furthermore, the drying fluid nozzle 6d is sufficient that inner diameter of the drying fluid nozzle 6d and others are determined so as to determine the flowing quantity of the drying fluid to be equal to or greater than 0.1 cc/min and equal to or less than 20 cc/min. The drying fluid nozzle 6d is preferable that inner diameter of the drying fluid nozzle 6d and the like are determined so as to determine the flowing quantity of the drying fluid to be equal to or greater than 0.5 cc/min and equal to or less than 2 cc/min. Furthermore, the distance between the drying fluid nozzle 6d and the substrate 1 is sufficient to be greater than 0 mm and equal to or less than 500 mm. The distance between the drying fluid nozzle 6d and the substrate 1 is preferable to be equal to or greater than 50 mm and equal to or less than 150 mm. When the distance between the drying fluid nozzle 6d and the substrate 1 is determined in such manner, disadvantages are prevented from occurrence such that the liquid drops of the drying fluid are not smoothly supplied to the gap between the substrates, and that vibration of the liquid surface of the cleaning fluid or the like becomes greater, so that the speed of the liquid face becomes a speed which is substantially greater than the optimum speed of MARANGONI drying, consequently the cleaning fluid remains on the surface of the substrates. In the above embodiment, instead the pump 6e, it is possible that inert gas is supplied to the drying fluid nozzle 6d so as to suck the drying fluid through the drying fluid supplying pipe 6b and to blow

the sucked drying fluid as the liquid drops with the inert gas. In this case, generation of particles due to the driving section of the pump 6e is prevented from occurrence.

The drying fluid nozzle 6d is preferable to be made of chemical resistance material such as fluorine contained polymers {preferably, PFA, PCTFE, PEEK (polyetheretherketone)}. Biting is prevented even in hydrofluoric acid environment.

Operation of the substrate processing apparatus having the above arrangement is as follows.

First, the open and close valves 5b and 6c are closed, the open and close valve 4c is opened, and the pump 4f is driven by the control section 10. In this condition, the processing fluid 11 is supplied to the processing fluid nozzle 4d through the processing fluid pipe 4b from the processing fluid tank 4a, then the processing fluid is blown within the processing vessel 2 from the processing fluid nozzle 4d. The processing fluid 11 blown within the processing vessel 2 is regulated by the regulation plate 4e and is guided to the substrate housing space so that the processing for the surface of the substrates 1 (for example, cleaning processing or the like) is carried out. During this processing, the processing fluid 11 overflowed from the processing vessel 2 is collected by a collection mechanism (not illustrated). Further, entire surface of all substrates 1 are processed almost uniformly by determining the flowing speed of the processing fluid 11 corresponding to the center of the substrate 1 to be the fastest speed.

After the processing of the substrates 1 by the processing fluid 11 has been finished, the open and close valve 4c is closed, the open and close valves 5b and 6c are opened, and the pump 6e is driven by the control section 10. Under this condition, the processing fluid 11 is exhausted through the exhausting pipe 5a from the processing vessel 2 so that the liquid face of the processing fluid 11 gradually descends. At the same time, the drying fluid is supplied to the drying fluid nozzle 6d through the drying fluid supplying pipe 6b from the drying fluid tank 6a and is blown as the liquid drops within the processing vessel 2 from the

drying fluid nozzle 6d so that the liquid layer of the drying fluid is formed on the liquid face of the processing fluid 11. This liquid layer is rapidly formed to have a relatively thick thickness because the drying fluid is supplied under the liquid drop condition. In other words, when the drying fluid is supplied under the mist condition, the diameter is equal to or less than 100 μm so that it is difficult to supply the drying fluid to the center section or lower section of the substrates 1 under the condition in which the interval between the substrates 1 is small. Consequently, it is difficult to increase the thickness of the liquid layer of the drying fluid. When this embodiment is employed, the drying fluid is supplied under the liquid drop condition so that it is possible to supply the drying fluid to the center section or lower section of the substrates 1 under the condition in which the interval between the substrates 1 is small. Consequently, it is possible to increase the thickness of the liquid layer of the drying fluid. As a result, superior drying of the substrates 1 is realized.

The substrates 1 are gradually exposed from the liquid face of the processing fluid 11 following the gradually descending of the liquid face of the processing fluid 11. But, liquid layer of the drying fluid is formed on the exposed section of the substrates 1 so that the exposed section is rapidly and uniformly dried by the MARANGONI effect.

Therefore, entire surface of the substrates 1 is rapidly and uniformly dried by the MARANGONI effect, finally. Of course, the processing fluid 11 is prevented from remaining on the surface of the substrates 1.

The supported section among the surface of the substrates 1 supported by the supporting groove 3b of the first substrate supporting section 3 contacts the first substrate supporting section 3 and very small space exists beneath the substrates 1. Therefore, drying of this section may be insufficient (insufficient in drying degree, and required time for drying). But, when a slit 3c is formed in continuous to the supporting groove 3b, and when a round hole 3d is further formed corresponding to the necessity,

drainage of the processing fluid is improved by the slit 3c and the round hole 3d so that drying of the section is sufficient.

When this embodiment is employed, the thickness of the liquid layer of the drying fluid can be determined to be greater. Therefore, the liquid layer of the drying fluid is formed up to the inner section (concave section) of the pattern so as to rapidly and uniformly dry the entire surface of the substrates 1 including the inner section of the pattern by the MARANGONI effect, even when the substrates 1 are employed which are formed the pattern on their surface. As a result, substrates having a high aspect ratio can be dealt.

Further, the blowing speed of the liquid drops of the drying fluid is determined to be the above speed, the drying fluid is securely supplied onto the liquid face of the processing fluid 11 so as to form the liquid layer of the drying fluid even when the interval between the substrates 1 is determined to be small. Of course, the liquid layer of the drying fluid is formed on the exposed portion of the substrates 1 from the liquid face of the processing fluid 11.

Furthermore, it is preferable to carry out the above processing under the room temperature. In this case, heating devices are not needed so that the arrangement of the substrate processing apparatus can be simplified, and the safety is improved.

Fig. 3 is a schematic diagram of a main portion of a substrate processing apparatus of another example, while Fig. 4 is a schematic diagram of a main portion of a substrate processing apparatus of a further example.

These substance processing apparatus are different from the substrate processing apparatus illustrated in Fig. 1 only in the number of drying fluid nozzles 6d. Specifically, the substrate processing apparatus illustrated in Fig. 3 has two drying fluid nozzles 6d, while the substrate processing apparatus illustrated in Fig. 4 has three drying fluid nozzles 6d.

When those examples are employed, entire surface of the substrates 1 are dried uniformly, even when the substrates 1

becomes large in size and when the interval between the substrates 1 becomes small.

Fig. 5 is a schematic diagram of a main portion of a substrate processing apparatus of a yet example.

This substrate processing apparatus is different from the above embodiment only in that an inert gas supplying section 7 is further provided which has an inert gas tank 7a, an inert gas supplying pipe 7b for guiding inert gas such as nitrogen or the like from the inert gas tank 7a, an open and close valve 7c and pump 7d each provided at a predetermined position of the inert gas supplying pipe 7b, and an inert gas nozzle 7e for blowing the inert gas supplied through the inert gas supplying pipe 7b. The inert gas nozzle 7e can be united with the drying fluid nozzle 6d. Further, the flowing quantity of the inert gas is sufficient to be greater than 0 liter/min and equal to or lesser than 200 liter/min. The flowing quantity of the inert gas is preferable to be greater than 5 liter/min and equal to or lesser than 20 liter/min. Furthermore, the inert gas supply section 7 is controlled by the control section 10.

When this example is employed, disadvantage is prevented from occurrence in that the interior of the processing vessel 2 becomes negative pressured condition with respect to the exterior so that particles intrude from the exterior, by supplying the inert gas within the processing vessel 2.

Further, it is preferable that the flowing quantity of the liquid drops 12 of the drying fluid and/or the flowing quantity of the inert gas are increased when the processing fluid is exhausted. The liquid drops 12 of the drying fluid is securely supplied to the liquid face of the processing fluid 11 so as to form the liquid layer of the drying fluid even when the liquid face of the processing face is descended.

Furthermore, the interior of the processing vessel 2 can be made to be the inert gas environment prior to the exhausting of the processing fluid. In this case, generation of water marks on the substrates 1 is suppressed.

Fig. 6 is a schematic diagram of a main portion of a substrate processing apparatus of yet another example.

This substrate processing apparatus is different from the above embodiment only in that an elevation section 8 for moving the drying fluid nozzle 6d up and down. Wherein, well known moving to and fro mechanism such as rack and pinion mechanism, piston mechanism, or the like is employed as the moving to and fro mechanism 8. And, the elevation distance is sufficient to be greater than 0 mm and equal to or less than 500 mm. The elevation distance is preferable to be equal to or greater than 250 mm and equal to or less than 350 mm. The elevation mechanism 8 is also controlled by the control section 10.

When this example is employed, the drying fluid nozzle 6d is descended when the processing fluid is exhausted. Therefore, the liquid drops 12 of the drying fluid is securely supplied to the liquid face of the processing fluid 11 so as to form the liquid layer of the drying fluid even when the liquid face of the processing face is descended (refer to Fig. 7).

Fig. 8 is a schematic diagram of a main portion of a substrate processing apparatus of a yet further example.

This substrate processing apparatus has a processing vessel 2, an outer vessel 13 for surrounding the processing vessel 2 which outer vessel 13 can be sealed, a first supporting member 14 for supporting the substrates (for example, semiconductor wafers) 1 in a standing condition and for transporting the substrates 1 to and from the processing vessel 2, and a second supporting member 15 which can be moved up and down and can be transport the substrates between the first supporting member 14. Further, the reference numeral 2a represents a cleaning fluid exhaust pipe for exhausting the cleaning fluid (for example, pure water) from the processing vessel 2.

The operation of the substrate processing apparatus having the above arrangement is as follows.

When the cleaning of the substrates 1 has finished, the processing vessel 2 is filled with the cleaning fluid (for example,

pure water) and the substrates 1 are supported by the first supporting member 14 in a natural condition and are dipped within the cleaning fluid. In this condition, the substrates 1 are apart from the second supporting member 15. Then, the drying fluid (for example, isopropyl alcohol vapor, mist or the like) is supplied within the outer vessel 13 through the cover body of the sealed outer vessel for drying the cleaned substrates 1, and the cleaning fluid is exhausted through the cleaning fluid exhausting pipe 2a from the processing vessel 2.

When this operation is carried out, the cleaning fluid is exchanged with the drying fluid layer so as to perform rapid drying in the exposed portion of the substrates 1 from the cleaning fluid.

When the exhausting of the cleaning fluid is continuously carried out, the liquid face of the cleaning fluid gradually descends. When the liquid face is positioned between the second supporting member 15 and the first supporting member 14, as is illustrated in Fig. 9, the second supporting member 15 is dried and the portion of the substrates 1 are also dried which are to be supported by the second supporting member 15.

Then, the second supporting member 15 is moved upward so as to engage the substrates 1 (refer to fig. 10). Thereafter, the first supporting member 14 is moved downward so that the substrates 1 are transferred from the first supporting member 14 to the second supporting member 15(refer to Fig. 11). During the transferring operation of the substrates 1, the relative position of the substrates 1 with respect to the processing vessel 2 is maintained to be a constant position. Therefore, the relative speed of the substrates 1 with respect to the liquid face of the cleaning fluid is maintained to be a constant speed so that the substrates 1 are dried uniformly.

Supplying of the drying fluid and exhausting of the cleaning fluid are carried out thereafter, so that the remaining portion of the substrates 1 and the first supporting member 14 are dried.

After the exhausting of the cleaning fluid has finished, no cleaning fluid remains on the contacted section of the substrates 1

to the first supporting member 14 and the second supporting member 15. Therefore, the drying fluid is exhausted from the interior of the processing vessel 2 and the outer vessel 13 by supplying the nitrogen gas through the cover body of the outer vessel 13 so that the drying processing of the substrates 1 is finished. As a result, usage quantity of the nitrogen gas can be decreased, and the entire processing time can be shortened.

When the drying processing has finished by performing the above operation, the dried substrates 1 can be taken out from the processing vessel 2 by opening the outer vessel 13 and by moving the first supporting member 14 upward.

When the substrates 1 are transferred in such manner, drying of the substrates 1 is finished by 4~5 minutes.

Specifically, when the semiconductor wafer is employed as the substrate 1, IPA is employed as the drying fluid, the flowing quantity of the drying fluid is determined to be 4 cc/min, pure water is employed as the processing fluid, nitrogen is employed as the inert gas, the flowing quantity of the inert gas is determined to be 20 liter/min, the drying nozzle 6d made of PEEK is employed, a number of the drying nozzles 6d is determined to be 2, the diameter of the drying fluid blowing hole formed in the drying fluid nozzle 6d is determined to be 0.2 mm, the length of the drying fluid blowing hole (thickness of the wall member of the drying fluid nozzle 6d) is determined to be 1 mm, a number of the drying fluid blowing holes is determined to be 51 (corresponding to the 50 substrates 1), a vertical position of the drying fluid nozzle 6d is determined to be a position which is above the upper face of the substrate by 100 mm, a horizontal positions of the drying fluid nozzle 6d is determined to be a positions each position being apart from the center of the substrates 1 by 75 mm, the exhausting speed of the processing fluid is determined to be 2 mm/sec, and when the semiconductor wafers are dried by transferring the semiconductor wafers, the required time for drying was 4 minutes. Further, in this specific example, diameter of the

liquid drop was about 190 μ m, the thickness of the liquid layer of the drying fluid was 50 μ m which is an average within the entire dipping boundary face (the liquid layer is thick at the position which is directly under the drying fluid nozzle 6d, while the liquid layer is thin at the position which is near the edge of the substrates), and the blowing speed was 208 m/sec.

Fig. 12 is a schematic diagram of a main portion of a substrate processing apparatus of a further example.

This substrate processing apparatus is different from the above substrate processing apparatus in that the substrates 1 are supported under an inclined condition by a predetermined angle with respect to the vertical face instead the substrates 1 being supported under a vertical condition, and that the drying fluid nozzle 6d is inclined so as to blow the liquid drops 12 of the drying fluid to suit the inclination of the substrates 1. Wherein the inclination angle is sufficient to be greater than 0° and equal to or less than 30°. The inclination angle is preferable to be equal to or greater than 3° and equal to or less than 5°.

When this example is employed, drying of the substrates 1 which have already formed a pattern on one surface is carried out rapidly and uniformly. Further, disadvantages are prevented from occurrence such that the cleaning fluid within the inner section of the pattern is difficult to be exhausted, that the drying fluid is difficult to be supplied to the dipping boundary face, and that the cleaning fluid exhausted from the pattern drops onto the neighboring substrate.

Description is made in more detail.

When the pattern is formed on one surface of each substrate 1, it is sufficient that each substrate 1 is inclined so as to be the pattern formed face becomes a downward look. Under this condition, the concave section 1a formed following the formation of the pattern becomes a downward look to some degree, as is illustrates in Fig. 13, so that exhausting of the processing fluid 11 is smoothly performed from at least a partial part of the concave

section 1a which is positioned above the liquid face of the processing fluid 11 which gradually descends. As a result, the quantity of the processing fluid 11 remaining within the concave section 1a is greatly reduced, so that drying of the surface of the substrates 1 following the forming of the liquid of the drying fluid is realized more satisfactorily.

Fig. 14 is a schematic diagram illustrating substrate processing apparatus of a further example.

This substrate processing apparatus is different from the above example only in that the drying fluid supplying section 6 has a different arrangement.

The drying fluid supplying section of this example has a pair of drying fluid tanks 6a1 and 6a2, a first and second communication pipes 6b1 and 6b2 for communicating each drying fluid tank 6a1 or 6a2 and the drying fluid nozzle 6d, open and close valves 6c1 and 6c2 each provided at a predetermined position of each communication pipe 6b1 or 6b2, a first circulation pipe 6k for communicating predetermined positions of both communication pipes 6b1 and 6b2 which predetermined positions are upstream side with respect to the open and close valves 6c1 and 6c2, an open and close valve 6f provided at a predetermined position of the first circulation pipe 6k, a second circulation pipe 6g for communicating both drying fluid tanks 6a1 and 6a2, and an open and close valve 6h provided at a predetermined position of the second circulation pipe 6g. Further, the reference numeral 6I represents an inert gas supplying pipe for supplying inert gas to the drying fluid nozzle 6d, reference numerals 6j1 and 6j2 represent relief valves each provided at each drying fluid tank 6a1 or 6a2, reference numerals 6m1 and 6m2 represent inert gas supplying pipes for supplying inert gas to each drying fluid tanks 6a1 or 6a2, and reference numerals 6n1 and 6n2 represent open and close valves each provided at a predetermined position of each inert gas supplying pipe 6m1 or 6m2. Further, the open and close valves 6c1 and 6c2 have flowing quantity adjusting function. Furthermore, the drying fluid tank 6a1 is determined to be a main

tank, while the drying fluid tank 6a2 is determined to be a reserve tank.

When this example is employed, a condition for blowing the liquid drops 12 of the drying fluid and a condition for circulating the drying fluid can be selected by the following manner.

(1) When blowing operation is carried out for blowing the liquid drops of the drying fluid:

When this operation is carried out, the open and close valves 6n1, 6c1, 6c2 and 6j2 are opened by the control section, while the open and close valves 6f, 6n2, 6h and 6j1 are closed by the control section.

Under this condition, the inert gas is supplied to the drying fluid tank 6a1 through the inert gas supplying pipe 6m1 so that the drying fluid is transferred by pressure to the drying fluid nozzle 6d through the first communication pipe 6b1. The drying fluid nozzle 6d is supplied inert gas through the inert gas supplying pipe 6i. Therefore, the drying fluid and the inert gas are blown together from the drying fluid nozzle 6d, consequently the drying fluid is blown as liquid drops 12 (refer to solid arrows in Fig. 14).

(2) When blowing operation is not carried out:

When this operation is carried out, the open and close valves 6f, 6j1 and 6j2 are opened by the control section, while the open and close valves 6c1, 6c2, 6h, 6n1 and 6n2 are closed by the control section.

Under this condition, the communication between both drying fluid tanks 6a1 and 6a2 and the drying fluid nozzle 6d is intercepted, while the communication between both drying fluid tanks 6a1 and 6a2 is maintained. Therefore, the drying fluid within the drying fluid tank 6a1 is moved to the drying fluid tank 6a2 when the interior of the drying fluid tank 6a1 has a higher pressure (refer to dashed arrows in Fig. 14). Under this condition, the drying fluid is not consumed so that the consumption quantity of the drying fluid is reduced and that the running cost is reduced.

(3) When the drying fluid is moved from the drying fluid tank 6a2 to the drying fluid tank 6a1:

When this operation is carried out, the open and close valves 6h, 6j1 and 6n2 are opened by the control section, while the open and close valves 6c1, 6c2, 6f, 6j2 and 6n1 are closed by the control section.

Under this condition, both drying fluid tanks 6a1 and 6a2 are communicated by only the second communication pipe 6g, while the inert gas is supplied to only the drying fluid tank 6a2. Therefore, the drying fluid within the drying fluid tank 6a2 is moved to the drying fluid tank 6a1.
Further, during the drying fluid being circulated, the inert gas is supplied to the drying fluid tank 6a through the second communication pipe 6b2. Therefore, the pressure within the circulation passage is determined to be higher than the exterior pressure, so that particles are prevented from intruding from the exterior (refer to dashed arrows in Fig. 11).

Industrial Applicability

This invention is applicable to the usage for drying the surface of substrates such as semiconductor wafers, and realizes rapid and uniformly drying.